

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
 BING AI
 FISH & RICHARDSON P.C.,
 12390 EL CAMINO REAL
 SAN DIEGO, CA 92130

PCT

**NOTIFICATION OF TRANSMITTAL OF
 THE INTERNATIONAL SEARCH REPORT AND
 THE WRITTEN OPINION OF THE INTERNATIONAL
 SEARCHING AUTHORITY, OR THE DECLARATION**

(PCT Rule 44.1)

<p>Applicant's or agent's file reference 15670-114WO1</p> <p>International application No. PCT/US05/20242</p> <p>Applicant THE REGENTS OF THE UNIVERSITY OF CALIFORNIA</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;">Date of mailing <i>(day/month/year)</i></td><td style="width: 50%; padding: 5px;">FOR FURTHER ACTION See paragraphs 1 and 4 below</td></tr> <tr> <td colspan="2" style="padding: 5px;">International filing date <i>(day/month/year)</i> 07 June 2005 (07.06.2005)</td></tr> </table>	Date of mailing <i>(day/month/year)</i>	FOR FURTHER ACTION See paragraphs 1 and 4 below	International filing date <i>(day/month/year)</i> 07 June 2005 (07.06.2005)	
Date of mailing <i>(day/month/year)</i>	FOR FURTHER ACTION See paragraphs 1 and 4 below				
International filing date <i>(day/month/year)</i> 07 June 2005 (07.06.2005)					

1. The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

For more detailed instructions, see the notes on the accompanying sheet.

2. The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

Shortly after the expiration of 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

<p>Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201</p>	<p>Authorized officer <i>Lydia Seal Taylor</i> Victor J. Taylor Telephone No. 571-272-1750</p>
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Form PCT/ISA/220 (January 2004)

(See notes on accompanying sheet)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
 BING AI
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 SAN DIEGO, CA 92130


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NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing (day/month/year)	30 DEC 2005
Applicant's or agent's file reference 15670-114WO1	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US05/20242	International filing date (day/month/year) 07 June 2005 (07.06.2005)

Applicant
 THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

1. The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes
 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

For more detailed instructions, see the notes on the accompanying sheet.

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no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

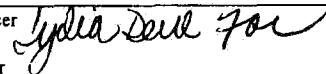
Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until **30 months** from the priority date (in some Offices even later); otherwise, the applicant must, within **20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer  Victor J. Taylor Telephone No. 571-272-1750
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 15670-114WO1	FOR FURTHER ACTION <small>see Form PCT/ISA/220 as well as, where applicable, item 5 below.</small>	
International application No. PCT/US05/20242	International filing date (day/month/year) 07 June 2005 (07.06.2005)	(Earliest) Priority Date (day/month/year) 07 June 2005 (07.06.2005)
Applicant THE REGENTS OF THE UNIVERSITY OF CALIFORNIA		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 8 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the Report

a. With regard to the **language**, the international search was carried out on the basis of:



the international application in the language in which it was filed.



a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2.

Certain claims were found unsearchable (See Box No. II)

3.

Unity of invention is lacking (See Box No. III)

4. With regard to the **title**,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 3



as suggested by the applicant.



as selected by this Authority, because the applicant failed to suggest a figure.



as selected by this Authority, because this figure better characterizes the invention.



b. none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/20242

Box IV TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)**NEW ABSTRACT**

Analyzing the integrated circuit using node model and dividing the node edges to form two sub graphs that represent two sub circuits of the integrated circuit with operating splitting method figure 3 for splitting and analyzing the two sub circuits for improved computation efficiency and improved processing speed.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/20242

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G06F 17/50
US CL : 702/081; 716/004

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 702/081; 716/004, 005, 006; 703/14-16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
STIC for publications on circuit analysis and SPICE programs.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST for key word and terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,557,148 B1 (Nishida et al.) 29 April 2003 (29.04.2003), see entire patent.	1-31.
A	US 6,308,300 B1 (Bushnell et al.) 23 October 2001 (23.10.2001), see entire patent.	1-31.

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

19 December 2005 (19.12.2005)

Date of mailing of the international search report

30 DEC 2005

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
Facsimile No. (571) 273-3201

Authorized officer

Victor J. Taylor

Telephone No. 571-272-1750

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
BING AI
FISH & RICHARDSON P.C.,
12390 EL CAMINO REAL
SAN DIEGO, CA 92130

PCT

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

(PCT Rule 43bis.1)

		Date of mailing (day/month/year)	30 DEC 2005
Applicant's or agent's file reference 15670-114WO1		FOR FURTHER ACTION See paragraph 2 below	
International application No. PCT/US05/20242	International filing date (day/month/year) 07 June 2005 (07.06.2005)	Priority date (day/month/year) 07 June 2005 (07.06.2005)	
International Patent Classification (IPC) or both national classification and IPC IPC(7): G06F 17/50 and US Cl.: 702/081; 716/004			
Applicant THE REGENTS OF THE UNIVERSITY OF CALIFORNIA			

1. This opinion contains indications relating to the following items:

<input checked="" type="checkbox"/>	Box No. I	Basis of the opinion
<input type="checkbox"/>	Box No. II	Priority
<input type="checkbox"/>	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
<input type="checkbox"/>	Box No. IV	Lack of unity of invention
<input checked="" type="checkbox"/>	Box No. V	Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
<input type="checkbox"/>	Box No. VI	Certain documents cited
<input type="checkbox"/>	Box No. VII	Certain defects in the international application
<input type="checkbox"/>	Box No. VIII	Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Date of completion of this opinion 19 December 2005 (19.12.2005)	Authorized officer Victor J. Taylor <i>Victor J. Taylor</i> Telephone No. 571-272-1750
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Form PCT/ISA/237 (cover sheet) (April 2005)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US05/20242

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:
 the international application in the language in which it was filed
 a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material
 a sequence listing
 table(s) related to the sequence listing
 - b. format of material
 on paper
 in electronic form
 - c. time of filing/furnishing
 contained in the international application as filed.
 filed together with the international application in electronic form.
 furnished subsequently to this Authority for the purposes of search.
3. In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.
PCT/US05/20242

Box No. V Reasoned statement under Rule 43 bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N) Claims 1-31 YES
Claims NONE NO

Industrial applicability (IA) Claims 1-31 **YES**
Claims NONE **NO**

2. Citations and explanations:

Claims 1-31 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the nodal modeling for circuit analysis with the circuit split into sub groups for processing and analysis.

Claims 1-31 meet the criteria set out in PCT Article 33(4), and thus provide the circuit analysis for node analysis and thus provide the industrial applicability because the subject matter claimed can be made or used in industry.

NOTESTOFORMPCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article," "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Preliminary Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under Article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

(12) United States Patent
Nishida et al.(10) Patent No.: US 6,557,148 B1
(45) Date of Patent: Apr. 29, 2003(54) CIRCUIT ANALYSIS TOOL AND
RECORDING MEDIUM HAVING RECORDED
PROGRAM FOR MAKING THE CIRCUIT
ANALYSIS TOOL FUNCTION(75) Inventors: Kouji Nishida, Tokyo (JP); Yasuji
Araki, Tokyo (JP)(73) Assignee: Mitsubishi Denki Kabushiki Kaisha,
Tokyo (JP)(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 168 days.

(21) Appl. No. 09/713,337

(22) Filed: Nov. 16, 2000

(30) Foreign Application Priority Data

Jan. 18, 2000 (JP) 2000-008936

(51) Int. Cl. 7 G06F 17/50

(52) U.S. Cl. 716/4; 716/5; 716/6

(58) Field of Search 716/4-6; 703/14-16

(56) References Cited

U.S. PATENT DOCUMENTS

6,374,205 B1 * 4/2002 Kuribayashi et al. 703/14

FOREIGN PATENT DOCUMENTS

JP 5-312905 11/1993

* cited by examiner

Primary Examiner—Matthew Smith

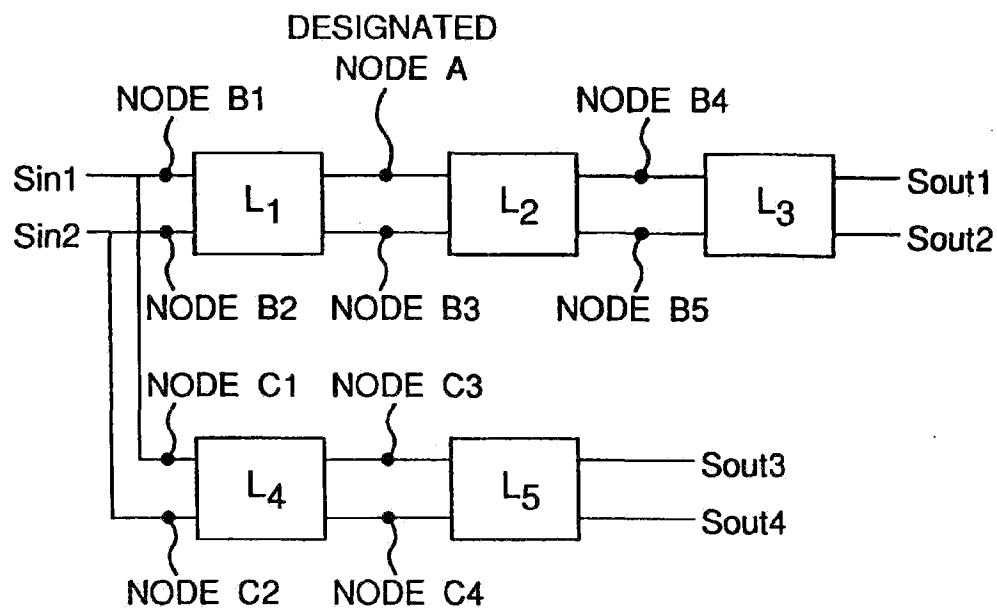
Assistant Examiner—Brandon Bowers

(74) Attorney, Agent, or Firm—McDermott, Will & Emery

(57) ABSTRACT

Provided is a circuit analysis tool having a function that enables the use of a high-accuracy simulator of SPICE2 or the like while reducing the time required for processing from the first simulation. The circuit analysis tool of the present invention distinguishes between a circuit element in which voltage and current values or a signal value change or changes in response to the input of a test signal and a circuit element in which no change of the values or value occurs on the basis of connection information of a semiconductor integrated circuit. The circuit element in which no change of the values or value occurs in response to the input of the test signal is replaced by an equivalent constant voltage terminal or grounding terminal, reducing the number of circuit elements to be subjected to simulation to be continuously executed (the amount of data of circuit information).

9 Claims, 7 Drawing Sheets





US006308300B1

(12) **United States Patent**
Bushnell et al.

(10) Patent No.: **US 6,308,300 B1**
(45) Date of Patent: **Oct. 23, 2001**

(54) **TEST GENERATION FOR ANALOG CIRCUITS USING PARTITIONING AND INVERTED SYSTEM SIMULATION**

(75) Inventors: Michael L. Bushnell, Princeton Junction; Rajesh Ramadoss, Piscataway, both of NJ (US)

(73) Assignee: Rutgers University, Piscataway, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 09/326,516

(22) Filed: Jun. 4, 1999

(51) Int. Cl. 7 G06F 17/50; H01H 31/02

(52) U.S. Cl. 716/4; 716/7; 716/2; 324/537

(58) Field of Search 716/4

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,202,639 * 4/1993 McKeon et al. 324/537
5,383,194 * 1/1995 Sloan et al. 371/22.1
5,422,891 * 6/1995 Bushnell et al. 371/22.4
5,831,437 * 11/1998 Ramadoss et al. 324/537

OTHER PUBLICATIONS

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R. Ramadoss et al., Test Generation for Mixed Signal Devices using Signal Flow Graphs, Ninth International Conference on VLSI Design, pp. 242-248, Jan. 1996.*

N. Nagi et al., Drafts: Discretized Analog Circuit Fault Simulator, Proceedings of 30th International Conference of Design Automation, pp. 509-514, Jun. 1993.*

Bryant, R. "Mossim: A Switch-Level Simulator for MOS LSI" 18th Design Automation Conference, Paper 41.2, pp. 786-790, 1981.

Pillage, L. "Asymptotic Waveform Evaluation for Timing Analysis" IEEE Transactions on Computer-Aided Design, vol. 9, No. 4 pp. 352-366, Apr. 1990.

Duhamel, P. et al., "Automatic Test Generation Techniques for Analog Circuits and Systems: A Review" IEE Transactions on Circuits and Systems, vol. CAS-26, No. 7 pp. 411-440, Jul. 1979.

Nagi, N. et al., "Drafts: Discretized Analog Circuit Fault Simulator" 30th ACM/IEEE Design Automation Conference, pp. 509-514, 1993.

Ho, C. et al. "The Modified Nodal Approach to Network Analysis" IEEE Transactions on Circuits and Systems, vol. CAS-22, No. 6, Jun. 1975.

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* cited by examiner

Primary Examiner—Matthew Smith

Assistant Examiner—A. M. Thompson

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(57) **ABSTRACT**

The present invention relates to a method and apparatus for testing analog and mixed analog and digital circuits in which test waveforms are generated for testing the analog circuit. The analog circuit can be represented by a directed circuit graph. The directed circuit graph represents nodes of components of the circuit under test connected by directed edges for components having inputs or outputs which effect other components and undirected edges for components in the circuit that are bidirectional. For example, undirected edges are assigned to bidirectional elements such as resistors and capacitors and directed edges are assigned to transistors. The directed graph is partitioned into partitions that carry a signal from the primary inputs toward the primary outputs in the circuit under test. Feedback and local feedback are captured in a single partition. The partition of a faulty component is determined and the operating point of the partition is established to activate the fault. The fault effects on the transfer function of each partition are determined by fault sensitization and fault effect propagation.

21 Claims, 12 Drawing Sheets

